Scanning Electron Microscopy of Saccular Intracranial Aneurysms

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Eight intracranial saccular aneurysms from 6 autopsies were studied with the scanning electron microscope and the cerebral arteries from control autopsies and rabbits were compared. The intima of the aneurysms had a more uneven and rugged surface than the surroundings. Only slight atherosclerotic changes were discovered in the immediate vicinity of the aneurysms. The windows of the internal elastic lamella were enlarged at the mouth of the aneurysms; the edge of the muscle layer was rounded and showed fibrosis. The structure of the walls of the aneurysms differed from that of the control arteries because they were composed of collagenous connective tissue. The adventitia of the aneurysms resembled that of control arteries. The findings are in accord with the assumption that saccular aneurysms develop at sites of developmental media defects. The internal elastic lamella over the area of the media defect shows primarily compensatory hypertrophy and later degeneration, extension and decay (Am J Pathol 68:511–520, 1972).

NORMAL ARTERIES AND ARTERIES from animals with experimental cholesterol atherosclerosis were studied by scanning electron microscopy.[1-3]

The morphology of intracranial saccular aneurysms under the light microscope is well known.[4] The transmission-electron-microscopic appearance of the aneurysms and media defects also have been studied.[5,6]

Many problems concerning the etiology, pathogenesis and treatment of saccular intracranial aneurysms are still unresolved. When an aneurysm is formed, the two normal main layers of the cerebral arterial wall—*ie*, the muscle coat and the internal elastic lamella, disappear and are replaced by collagenous connective tissue. It has been assumed, on good grounds,[4] that aneurysms develop at sites of developmental media defects, but this assumption has not been definitely proven. Knowledge of how the internal elastic lamella is destroyed is very incomplete. The possible connection between

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aneurysms and atherosclerotic intimal thickening has been debated.[7] The rate at which an aneurysm grows is not known. The present study was started in the hope that the new morphologic method, scanning electron microscopy, would provide new information that could be of value for future attacks on these problems.

Material and Methods

Eight saccular intracranial aneurysms from 6 subjects were studied (Table 1). In those with multiple aneurysms, only the ruptured aneurysms and in 2 further cases one aneurysm were studied. The aneurysms were found on the anterior, middle cerebral internal carotid or basilar arteries. The specimens were taken 4 to 31 hours postmortem. Cadavers were kept at 3 to 6 C for most of the time. In one case, fixation was carried out by the injection of 10% formalin (buffered to pH 7 by a phosphate buffer) under a pressure of 30 mm Hg for 2 hours. In 3 cases, 2.5% glutaraldehyde buffered with 0.1 M of cacodylate at pH 7.3 was used instead of formalin. In one aneurysm that had ruptured recently, the blood clots of the aneurysm were removed by washing in physiologic saline. Fixation was then performed in 2.5% glutaraldehyde buffered with cacodylate. Three aneurysms were dehydrated intact; the others were cut with a pair of scissors or torn into pieces.

Control material was taken from the anterior and middle cerebral arteries of 8 subjects examined 6 to 43 hours postmortem (Table 1). In 3, the material was fixed in formalin and the remaining were fixed in glutaraldehyde as described above.

In addition, another kind of control material was taken from 4 young rabbits, weighing 1.4 to 1.6 kg. The animals were anesthetized with Mebumal® (ACO,

Table 1—Some Data on Subjects with Aneurysm and Control Subjects

Case	Age	Sex	Chief disease	No. of aneurysms	Enlargement of left side of heart (as reported at autopsy)	Weight of heart (g)
Subjects with aneurysms						
1	50	F	Subarachnoid hemorrhage	1	+	450
2	52	M	Subarachnoid hemorrhage	3	+	470
3	54	F	Subarachnoid hemorrhage	3	+	390
4	54	M	Subarachnoid hemorrhage	2	+	400
5	59	M	Subarachnoid hemorrhage	1	+	450
6	61	F	Subarachnoid hemorrhage; postoperative thrombosis with cerebral infarction	2	—	300
Control subjects						
7	4	M	Astrocytoma	—	—	70
8	32	F	Astrocytoma	—	—	290
9	47	M	Laennec's cirrhosis	—	+	420
10	49	M	Gastric carcinoma	—	—	330
11	53	M	Myocardial infarction	—	+	560
12	61	F	Carcinoma of breast	—	—	270
13	63	F	Carcinoma of colon	—	—	280
14	68	M	Myocardial infarction	—	+	460

Stockholm, Sweden) and killed by excising the heart and injecting 2.5% glutaraldehyde into the aorta under a pressure of 30 mm Hg. The two largest branching points of the cerebral, mesenteric and femoral arteries were excised, fixed for 2 hours in ice-cold 2.5% glutaraldehyde buffered with 0.1 M of cacodylate at pH 7.3.

After fixation, all of the specimens were washed in several changes of distilled water and freeze-dried. A conducting coat of approximately 100 to 200 Å of gold was deposited (Pirani Penning, model 4, Edwards, England). The specimens were studied with a scanning electron microscope (Cambridge Stereoscan S 4). The material was finally embedded in paraffin wax and sections, stained with Gomori's elastin stain combined with van Gieson's stain, were produced from several levels.

Results

The appearance of one of the intact aneurysms is shown in Figure 1. The perivascular net of arachnoidal fibers (Figure 1B) resembled that of the surroundings and of the control materials. The internal surface of the aneurysm (Figure 2A) was somewhat uneven and rugged, with an irregular pattern of small ridges and gullies. Thus, it differed from that of the autopsy control material (Figure 2B). The surface of the cut or torn wall of the aneurysm, consisting of collagenous connective tissue, had a finely granulated, compact appearance (Figure 3A) differing from that of the tunica media (Figures 3B, 4B), which was built up of fusiform, smooth-muscle cells. Similar, but less distinct, pictures of collagenous connective tissue were seen in the minimal media defects of the rabbit arteries. Photomicrographs of the site of the aneurysm rupture (Figure 2C) resembled those seen in Figure 3A.

The mouth of the aneurysms showed only very slight atheromatous changes of the intima. The surface of the cut or torn mouth of the aneurysm (Figure 3B) showed often dilated windows of the internal elastic lamella. No dilated windows could be discovered in the rabbit material. At the mouth of the aneurysm, there was a transition between the appearance of the aneurysm wall and the tunica media, due to fibrosis of the tunica media. The border of the muscle coat seemed to be rather smoothly rounded.

The intima cushions in the vicinity of the aneurysms (Figure 4) resembled other intima cushions in autopsy and rabbit arteries and consisted of elastic lamellae interspersed with layers of smooth-muscle cells (Figure 4B).

Photomicrographs of the paraffin sections showed typical saccular intracranial aneurysms occurring in all aneurysm cases. In seven branching points of the arteries of the rabbits, typical, but minute, media defects were observed.

Discussion

The intimal surfaces of the aneurysms were more irregular, with higher ridges and deeper gullies than those of the control material and those depicted in other works.[2] This may be due to the fact that the intima is newly formed and not particularly exposed to the forces of flowing blood. Only slight atherosclerotic changes were discovered in the neighborhood of the aneurysms, and they did not seem to have any relationship to the aneurysms. Thus, Carmichael's theory[7] of early atherosclerotic destruction of the vessel wall as the cause of aneurysm formation received no support.

The internal elastic lamella was thickened, with enlarged windows at the mouth of the aneurysms. This agrees with findings from other studies,[5,6] and agrees with the assumption that the elastic lamella becomes overstretched and hypertrophied.[4] No signs of degeneration of the elastic lamella could be demonstrated in the scanning-electron-microscope pictures.

The muscle coat showed a fibrosis and a rather soft border towards the aneurysms, a finding that confirms those of previous light-microscopic studies[4] and supports the assumption of a preexisting media defect formed by an error in development.

The adventitia resembled that of the normal cerebral artery. The growth of the aneurysms apparently is not more rapid than the rate at which adventitia of normal appearance is renewed. The adventitia showed no signs of external pressure, reinforcement or inflammation.

The rupture surfaces of the aneurysms resembled areas artificially torn or cut postmortem. They differed from similar areas of control arteries apparently because the aneurysms were composed of collagenous connective tissue, instead of the smooth muscle and elastic tissue of the control arteries.

It is obvious that autolytic changes occurred in the autopsy material. These changes resembled those observed by Shimamoto *et al*[2] and seem to be unavoidable in a study of aneurysms which, practically, only occur in man. The changes did not seem to be so important as to make other observations impossible. As a matter of fact, arteries are comparatively resistant to autolysis.[4]

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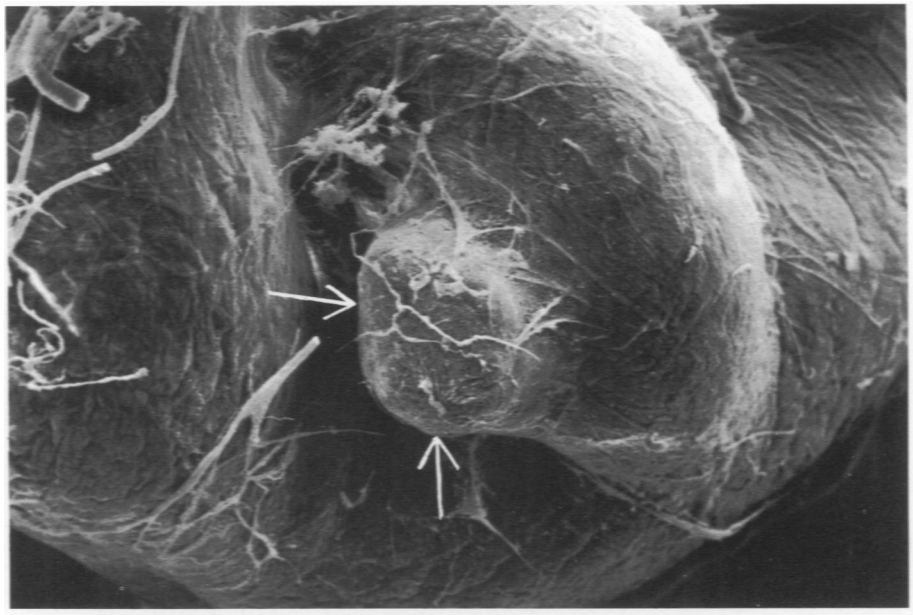
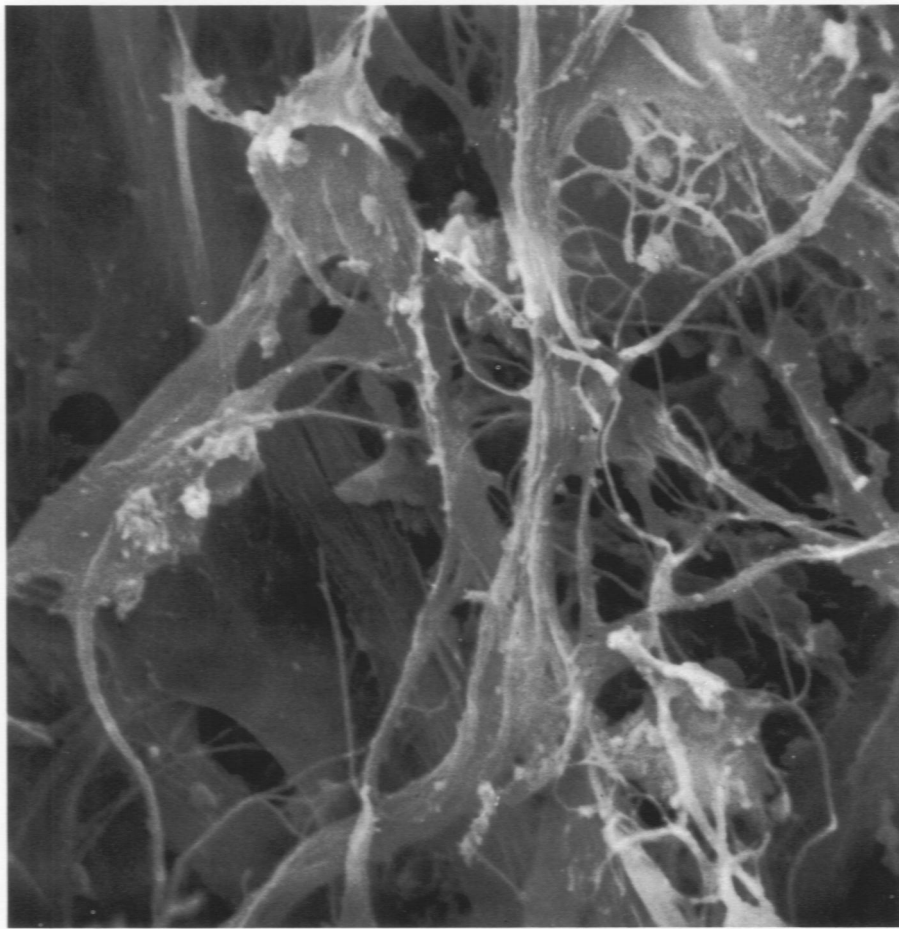
[Illustrations follow]

Fig 1A—The scanning-electron-microscopic appearance of an unruptured saccular intracranial aneurysm *(arrow)* on the middle cerebral artery (Case 2, × 28). **B**—Detail enlargement of a part of the external wall of the same aneurysm. The surface appearance of the adventitia of the aneurysms did not differ from that of the normal arterial wall (× 7000).



1A



1B

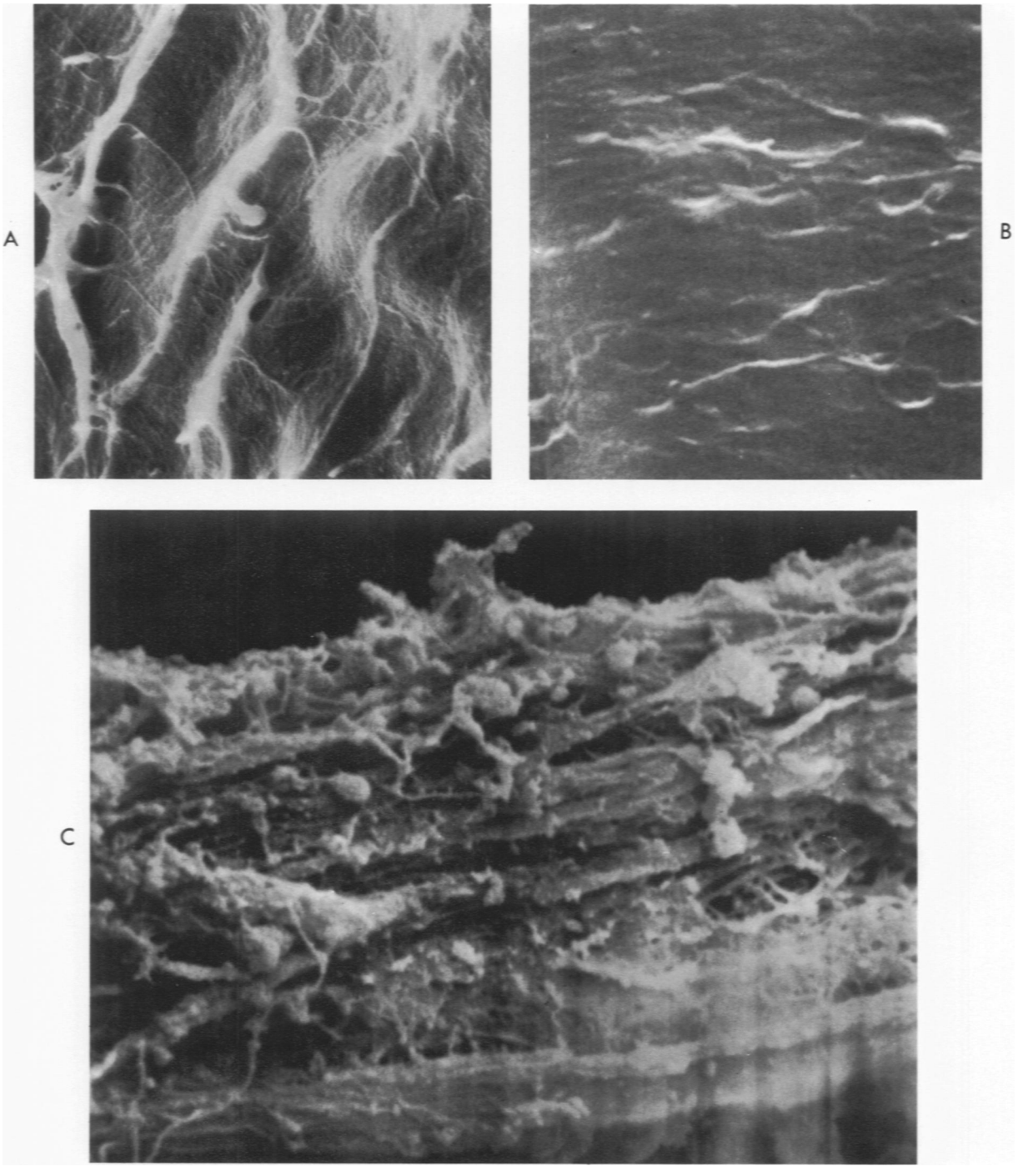


Fig 2A—Detail enlargement of the internal (intimal) surface of another aneurysm (Case 5). The intimal surface showed a rather irregular pattern, with small gullies and ridges (× 3400). **B**—Intimal surface of a control (middle cerebral artery of Case 10). The surface was smoother than that of the aneurysm (×3400). **C**—Rupture surface of an aneurysm (Case 4). Blood had to be washed away with a brush and physiologic saline. The surface resembles that in Figure 3A (× 6000).

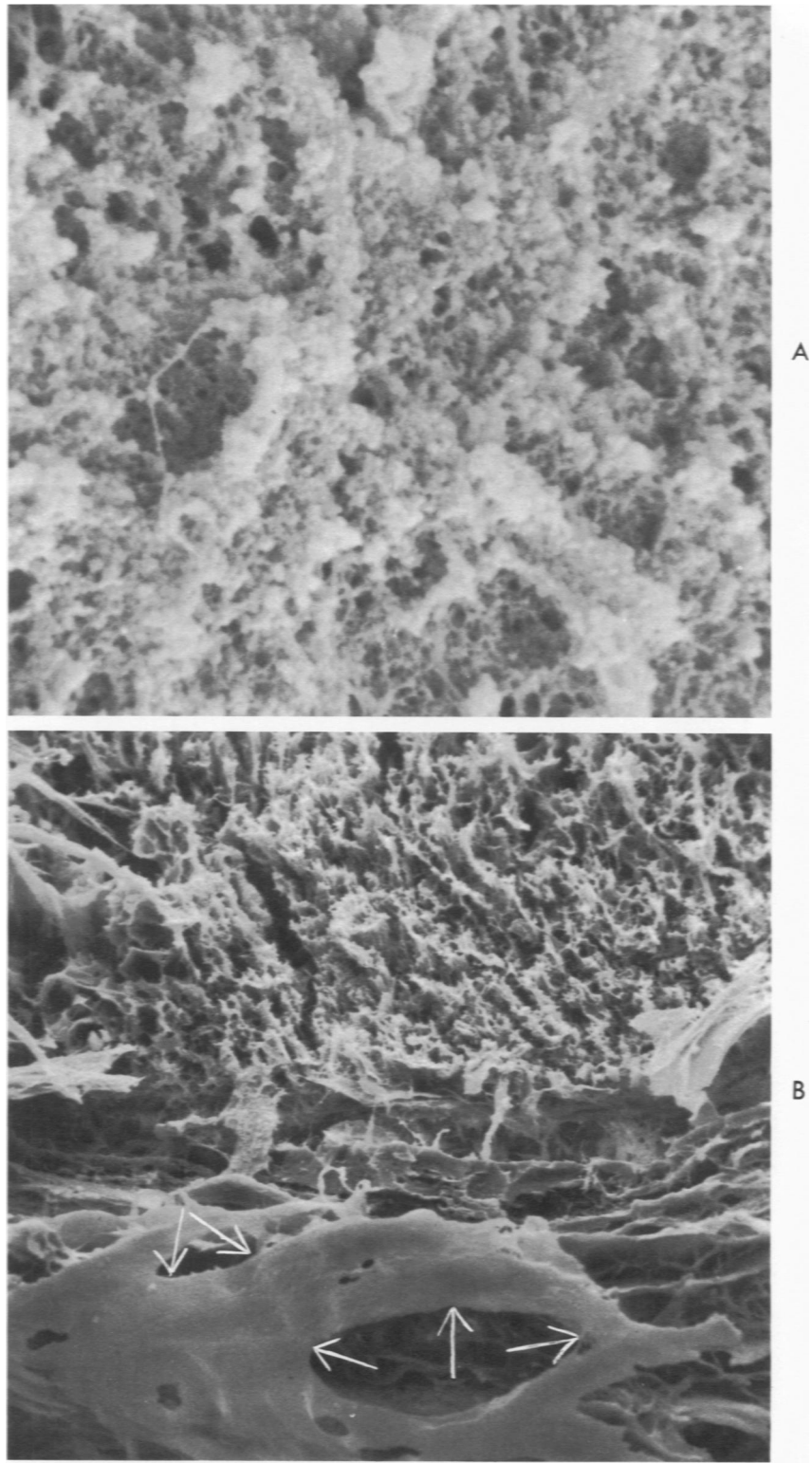


Fig 3A—The wall of an aneurysm sack. Surface of a torn portion which showed a compact, finely granulated appearance, apparently because it consisted mainly of collagenous connective tissue (compare with the smooth muscle of Figure 4B) (× 6000). **B**—Mouth of an aneurysm (Case 3). Surface of a cut portion of the wall which contains an internal elastic lamella (*bottom*) with enlarged windows (*arrows*) and smooth muscle (*top*) (× 1150).

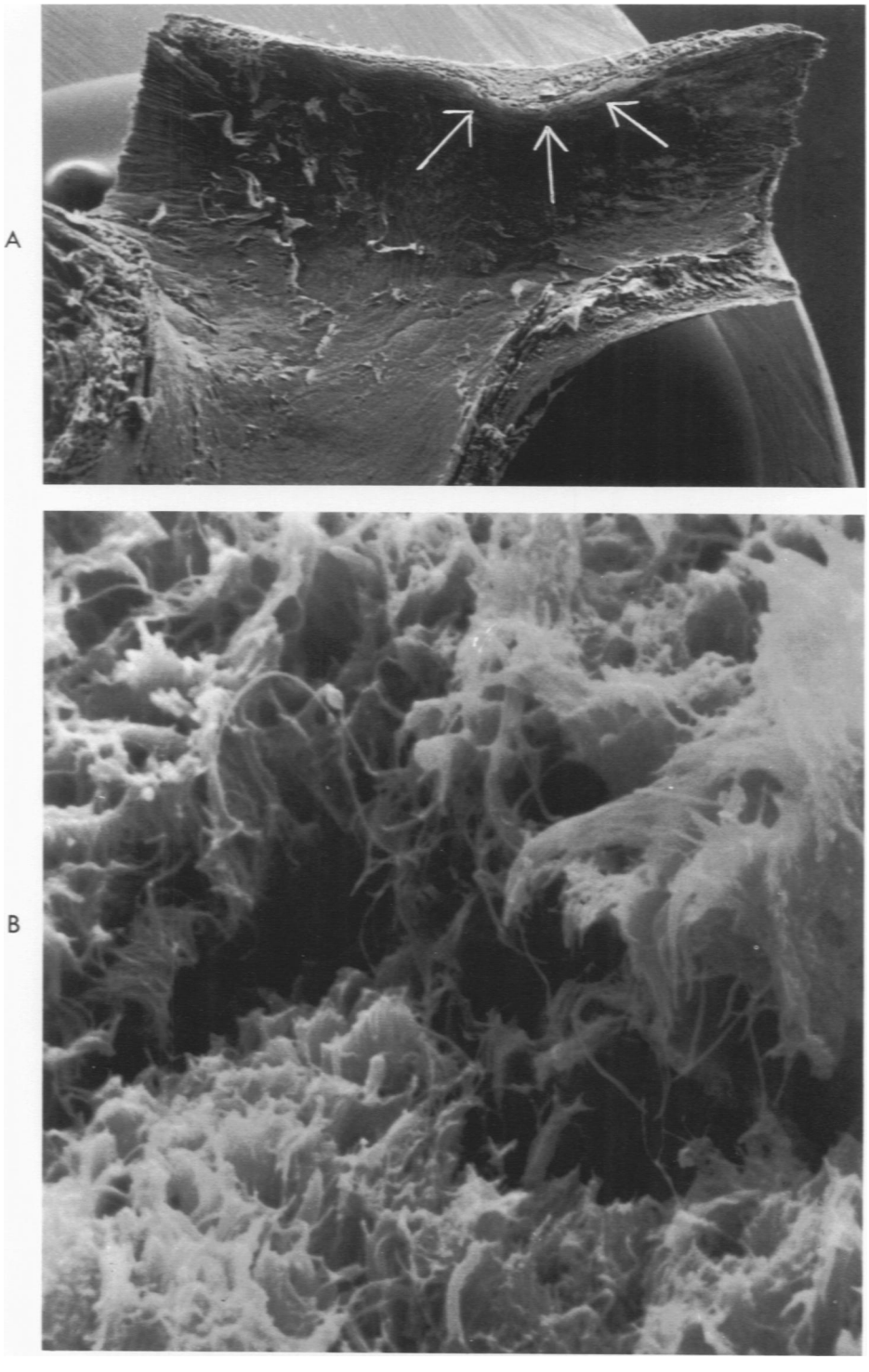


Fig 4A—Intima cushion (*arrow*) in the neighbourhood of an aneurysm. The lumen was opened by longitudinal incisions with a pair of scissors (× 28). **B**—Detail enlargement of a portion of the same cushion, showing smooth muscle and, in the middle of the figure, a dark empty area after the elastic lamella was torn away (× 6000).